The Agenda

Wednesday, January 14th

8:00-8:10	Introduction & Agenda Walk Through	Bernard D. Seery
8:10-8:15	Welcome	Dr. John Campbell/HST
8:15-8:30	Charge to the Board	Dr. Dick Kurz
8:30-9:45	Executive Summary	Bernard D. Seery
9:45-10:15	NGST -- The Big Picture	Dr. John Mather
10:15-10:30	Break	
10:30-11:00	Science Overview	Dr. Peter Stockman
11:00-11:45	Space Imaging & Spectroscopy Requirements	Dr. Pierre Bely
11:45-12:45	Lunch	
12:45-2:00	Systems Engineering Overview	Paul Geithner
2:00-2:45	Mission Architectures	Dr. Pierre Bely
2:45-3:15	Modeling & Simulation Demo	Gary Mosier/Dr. Dave Redding
3:15-3:30	Break	
3:30-4:30	Technology Program Overview	Dr. Dan Coulter
4:30-5:00	Discussion	Dr. Dick Kurz
5:00	Adjourn	

The Agenda (cont'd)

Thursday, January 15th

8:30-9:00	Cost & Processes	Lisa Guerra
9:00-9:30	Instruments	Dr. Richard Burg
9:30-10:00	Mission Operability	Dr. Keith Kalinowski
10:00-10:15	Break	
10:15-10:40	Optics Technology Roadmap	Jim Bilbro
10:40-11:00	Detector Technology	Dr Craig McCreight
11:00-11:45	TRW Technology Roadmap & Implementation Approach	Dr Chuck Lillie
11:45-1:00	Lunch	
1:00- 1:45	Ball Technology Roadmap & Implementation Approach	Wally Meyer
1:45-2:00	ESA Studies	Bernie Seery (for Koos Cornelisse)
2:00-3:00	Implementation Approach	Paul Geithner
3:00-3:15	Break	
3:15-4:00	Summary	Bernie Seery
4:00-4:15	Study Scientist's Perspective	John Mather
4:15-5:30	Board Caucus	Dick Kurz
5:30	Adjourn	

The Agenda (cont'd)

Friday, January 16th

8:30-11:00	Board Report Prep	Dick Kurz
11:00-11:30	Debrief	Dick Kurz
11:30	Adjourn	

Next Generation Space Telescope

Welcome

Dr. John H. Campbell

Associate Director, HST Project Manager

GSFC

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Charge to the Board

Dr. Richard Kurz

Gemini Project Manager

AURA

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Charge to the Board

Science Requirements

- Is the statement of the science requirements adequate to guide the project in the Phase A trade-off studies?

Systems Engineering

- Have our trades been sufficiently broad and balanced?
- Are our engineering processes and tools rational and adequate?
- Are the proposed concept architectures adequate and optimal?
- Is our approach to understanding the basic technical issues correct? How about our cost reduction and control methodologies?

Technology Program

- Is the technology plan addressing all the key technologies and is it synchronized with the project?
- Are our technology infusion and technology validation plans adequate? Aggressive enough?

Implementation Approach

- Are the Pre-Phase A plans and deliverables adequately defined and consistent with the overall implementation approach?
- Are our management approach, organization, and acquisition strategy adequate?
- Comment on our overall risk management strategy, particularly given the single Phase B contract approach.

Executive Summary

Bernard D. Seery

NGST Project Formulation Manager

GSFC

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Executive Summary

-- *Outline* --

- Background
- Objectives
- Environment
- Resources
- Development Schedule
- Technology Roadmap
- Technology Validation
- Acquisition Template
- Management Strategy
- Outreach
- Summary

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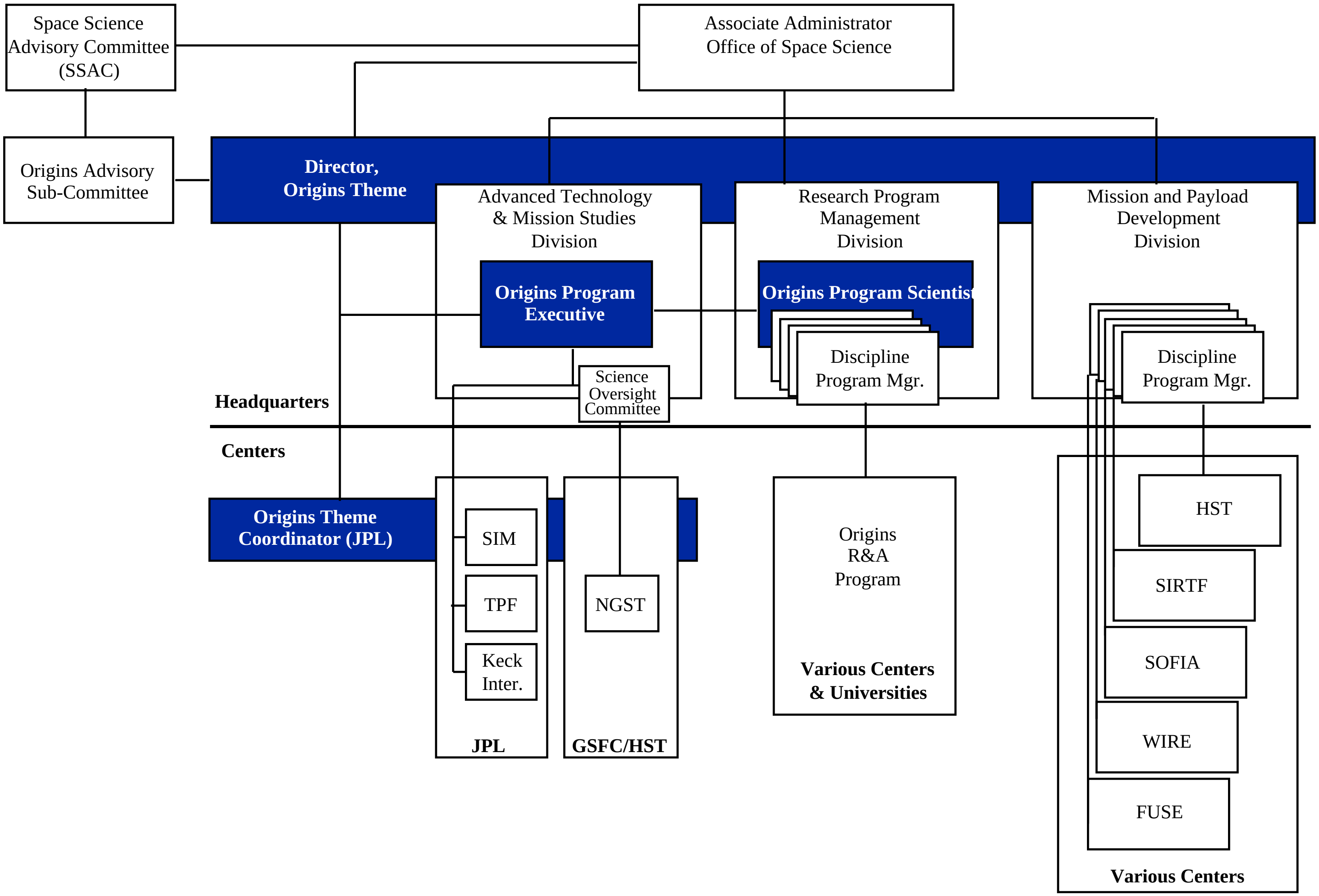
Dressler Committee Findings

- 1994, HST & Beyond Committee was charted by AURA and NASA to assess future needs for the UV/OPT/IR community for the years 2005 and beyond

RECOMMENDATIONS:

- The HST should be operated beyond its currently-scheduled termination date of 2005
- NASA should develop a space observatory of aperture 4m or larger, optimized for imaging and spectroscopy over the wavelength 1-5 μm
- NASA should develop the capability for space interferometry

Origins Context



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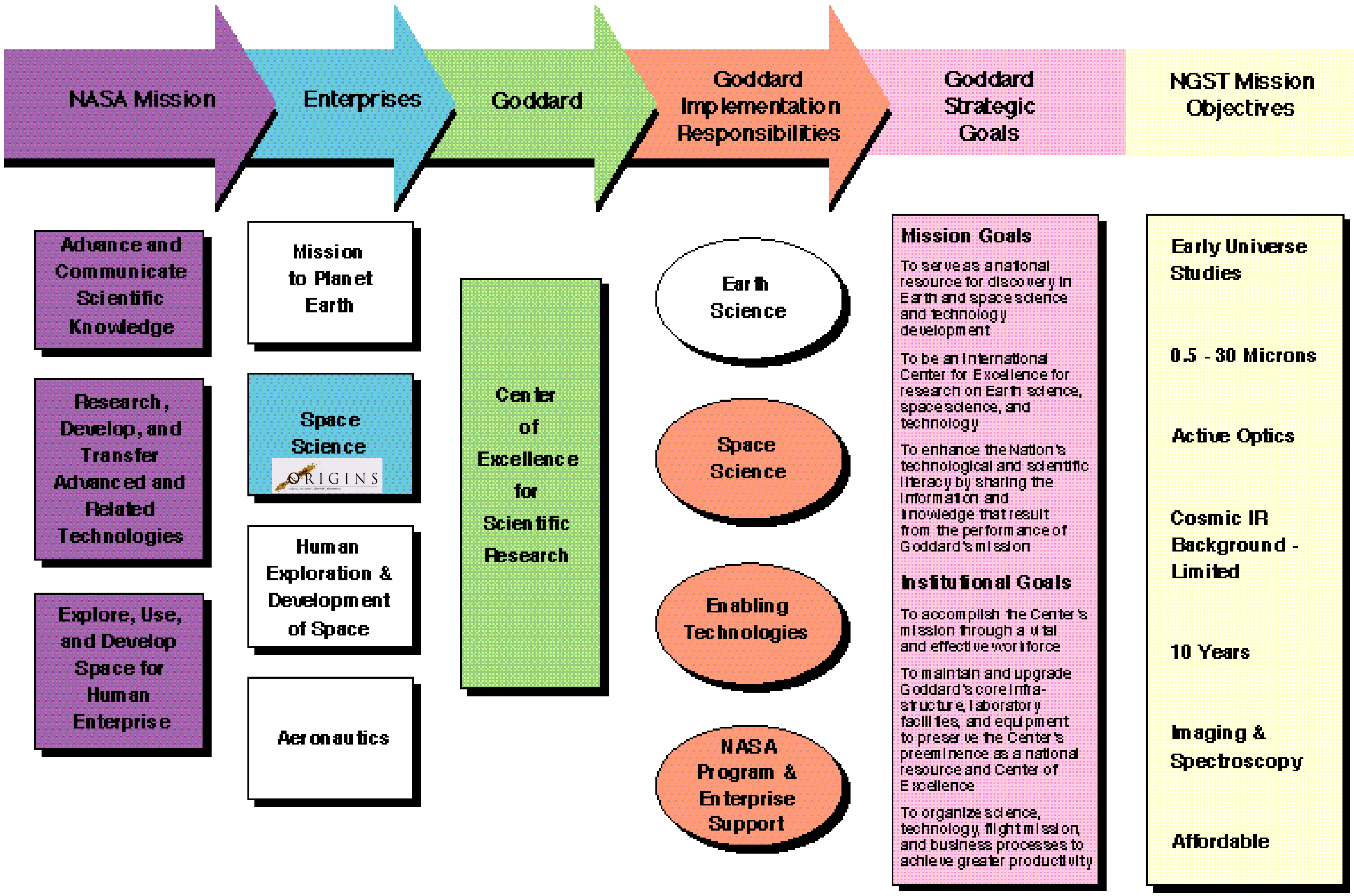
NGST Linkage to the Strategic Plan



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Next Generation Space Telescope

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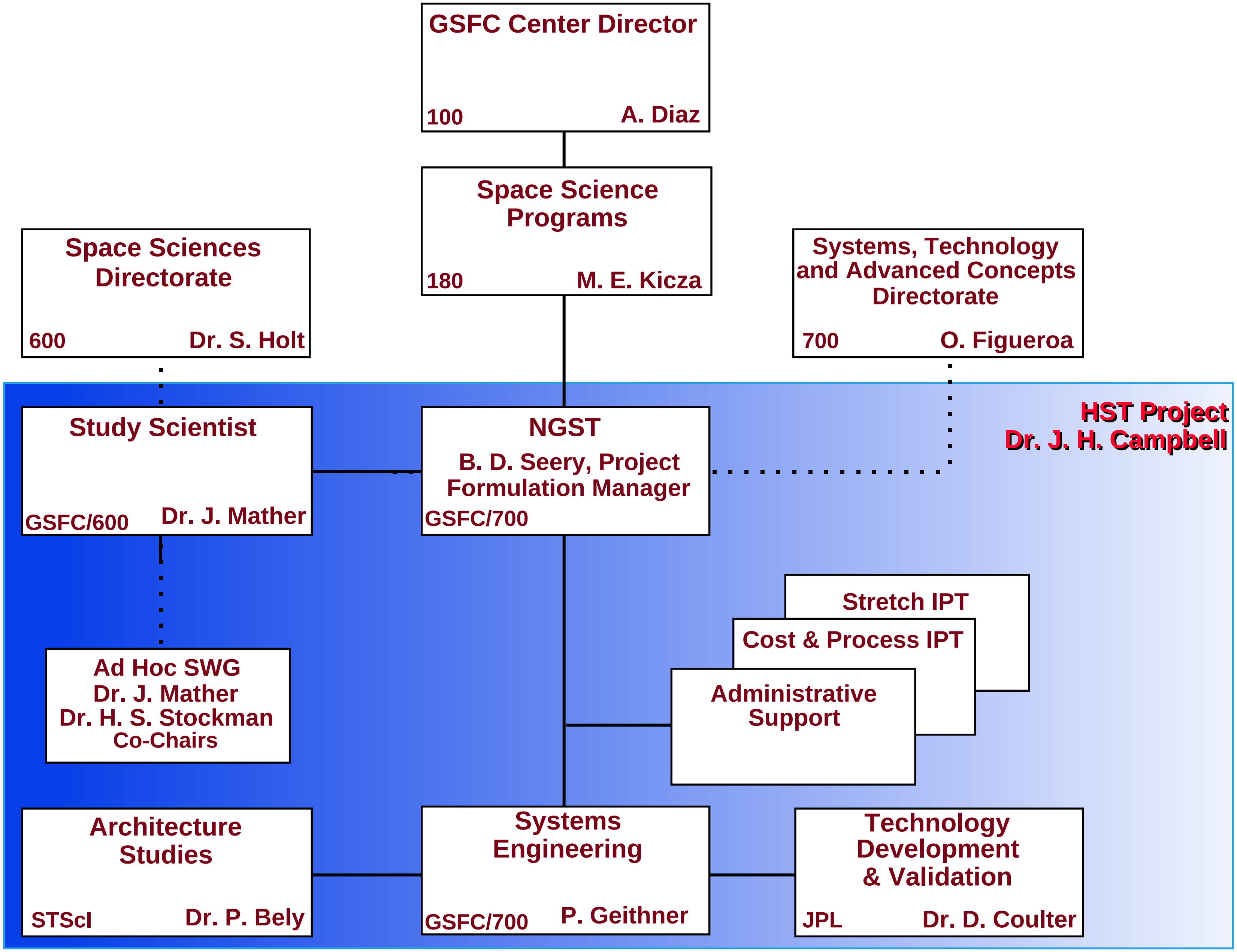

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Initialization of the Study - 1996

- Systems Engineering established the “Kernel” parameters to get the study effort going
  - Kernel parameter allocations included:
    - Launcher - Atlas II
    - Fairing - EPF
    - Mass
    - Volume
    - Cost bogey
- Given that the launch vehicle marketplace is rapidly changing in response to commercial requirements, our advice to the industry is to choose a launcher/ fairing combination with a known dynamic envelope and cost, and to carry that cost in the lifecycle estimate deliverable due at the end of the architecture study contract

Fig 139

Fig 140

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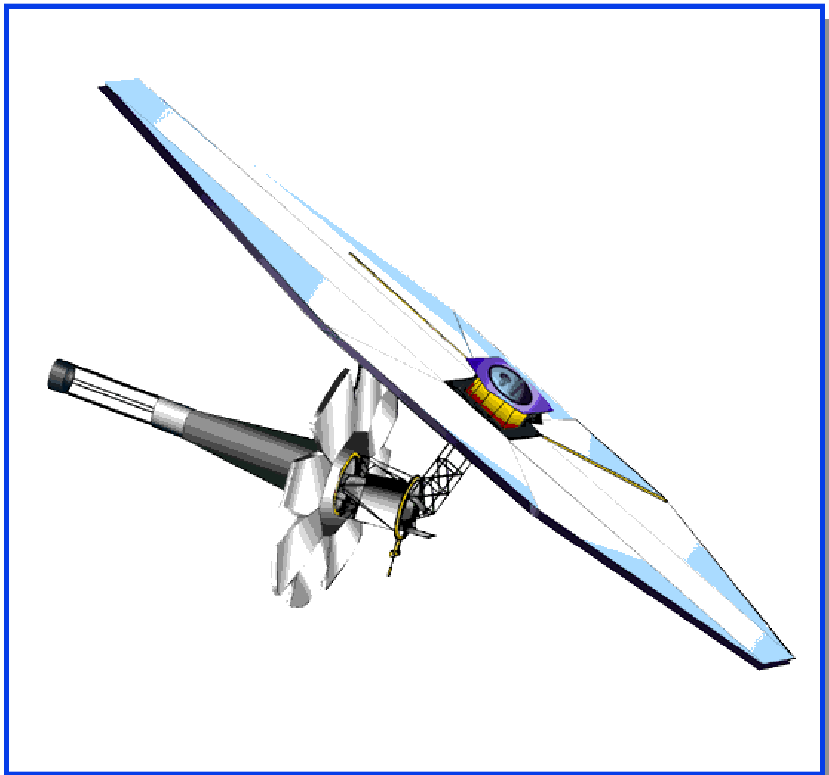
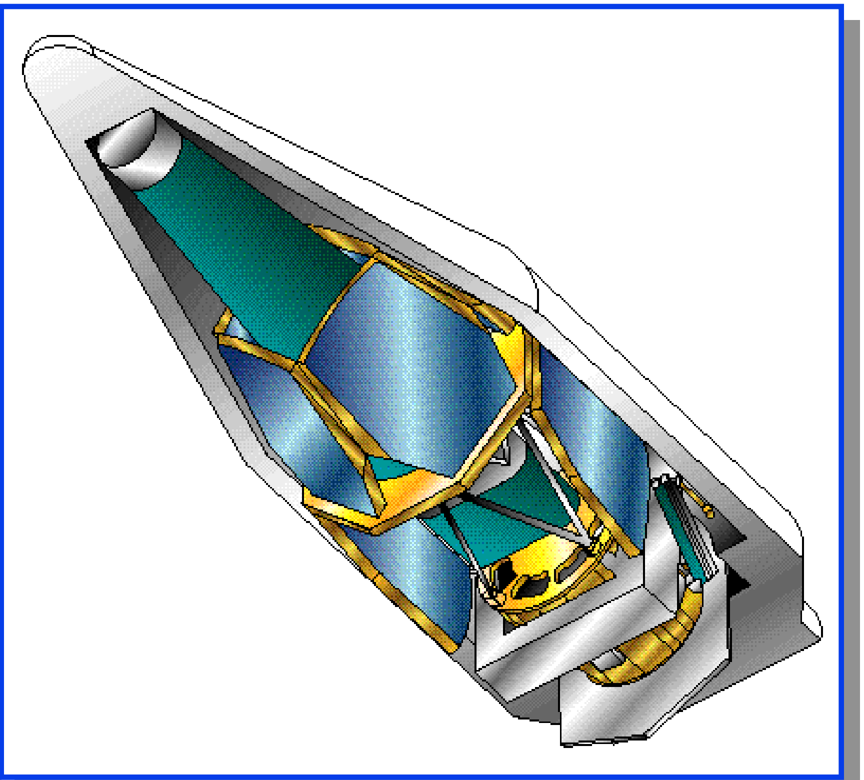
Reference Design Concept



8-Meter Segmented
Deployable at L2



ELV Launch Configuration

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HISTORY OF THE NGST PROJECT

1989: A NASA/STScI workshop on the Next Generation Space Telescope (NGST), demonstrates the science potential of a large telescope in space and delineates the main technical challenges.

Ref: The Next Generation Space Telescope, Workshop Proc., 1989

1991: The "Bahcall Decadal Report" recommends that a successor to HST be flown in the first decade of the new century.

Ref: The Decade of Discovery in Astronomy and Astrophysics - National Academy Press, 1991

1991: A series of meetings between academia and industry identifies the critical technologies for Large Telescopes in Space.

Ref: Large Aperture in Space, Astrotech 21, JPL report, 1991

1994: The Space Telescope Science Institute proposes a passively cooled 4m telescope in high orbit to expand on HST's discoveries of young galaxies.

Ref: High Z: A near-IR space telescope for probing the early universe, a proposal to New Mission Concepts for Astrophysics, by H.S. Stockman, STScI, 1994

HISTORY OF THE NGST PROJECT (cont'd)

1995: A task group recommends that an existing 4m BMDO prototype telescope be completed and launched for a dual military/astronomical purpose.

Ref: a scientific assessment of the new technology orbital telescope, National Academy Press, 1995.

1995: The "Dressler report" recommends that a 4-m class telescope, passively cooled to achieve maximum sensitivity in the near-IR, be flown soon after the end of HST's life.

Ref: Exploration and the search for Origins: a vision for UV-optical-IR space astronomy, report of the HST and Beyond Committee, AURA, 1996

1996: Mr. Goldin, NASA Admnistrator, challenges the astronomical community to "think big".

Ref: Address to the AAS meeting, San Antonio, Jan 1996

1996: An NGST Optics symposium held at MSFC explores the technologies required for NGST.

Ref: Symposium on optical systems concepts and technology for NGST, April 1996

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HISTORY OF THE NGST PROJECT (cont'd)

1996: Parallel studies by TRW, Lockheed Martin and NASA conclude it is feasible to fabricate an 8-meter class telescope for a maximum cost of $500M (total of $900M including launch and operations in 1996 dollars)

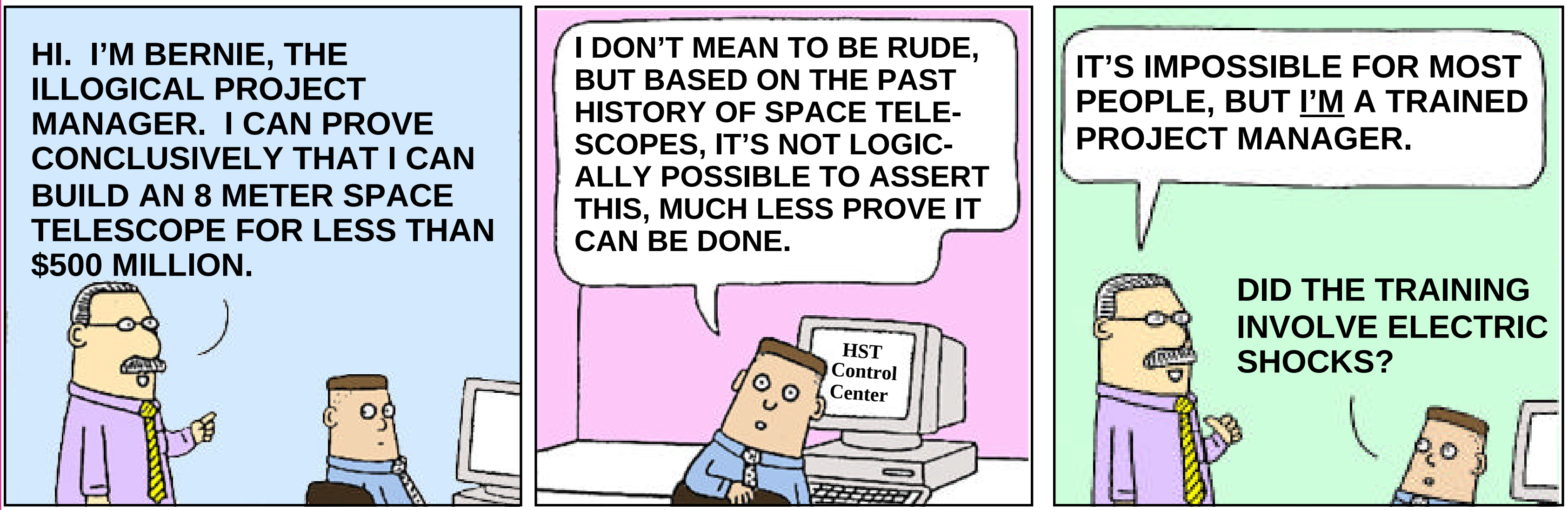
Ref: The Next Generation Space Telescope: Visiting a time when galaxies were young, H.S. Stockman, Ed., AURA, 1997

1997: Pre-Phase A studies being performed by TRW and Ball Aerospace. Ultra Lightweight Mirror Technology under development.

Top Level Goals

-- THE CHALLENGE --

- ***In the spirit of providing the scientific community with "order of magnitude" performance improvement at an "affordable" cost...***
  - **Provide a worthy successor to HST with the following features:**
    - **10 times the collecting area of HST**
    - **<25% of the launch mass of HST**
    - **<25% of the lifecycle cost of HST in real year dollars**



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Science and Engineering Goals

Parameter	HST	NGST Science Floor	NGST Stretch Goals
Wavelength Range	Ly α - 2 μm	1 - 5 μm	0.5 - 30 μm
Angular Resolution	Diffraction-Limited at 0.55 μm	Diffraction-limited at 2 μm	Diffraction-limited at 0.5 μm
Aperture Diameter	2.4m	> 4m	> 8m
Sensitivity	Instrument-Limited (NICMOS)	Zodi-limited at 1 AU	Cosmic infrared background-limited
Lifetime	15 years	> 5 years	10 years
Instruments	WFPC2, STIS, NICMOS, FOC, FGS	Wide Field Camera / Spectrometer	Add visible, TIR Camera / Spectrometer and Coronagraph

Fig 006a

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The Environment

- The Administrator will not give the go-ahead to a mission concept which is not at the cutting edge of technology
- Keep options open for as long as possible
  - *Just-in-time technology with off-ramps*
- Aggressively develop the enabling technologies so as to be ready to move into C/D by 2003
  - HST wedge post-2002
- Minimize the risk of an “architecture failure” in Phase B or early C/D
  - Robust Pathfinder 3 experiment
  - “Hot Spare”

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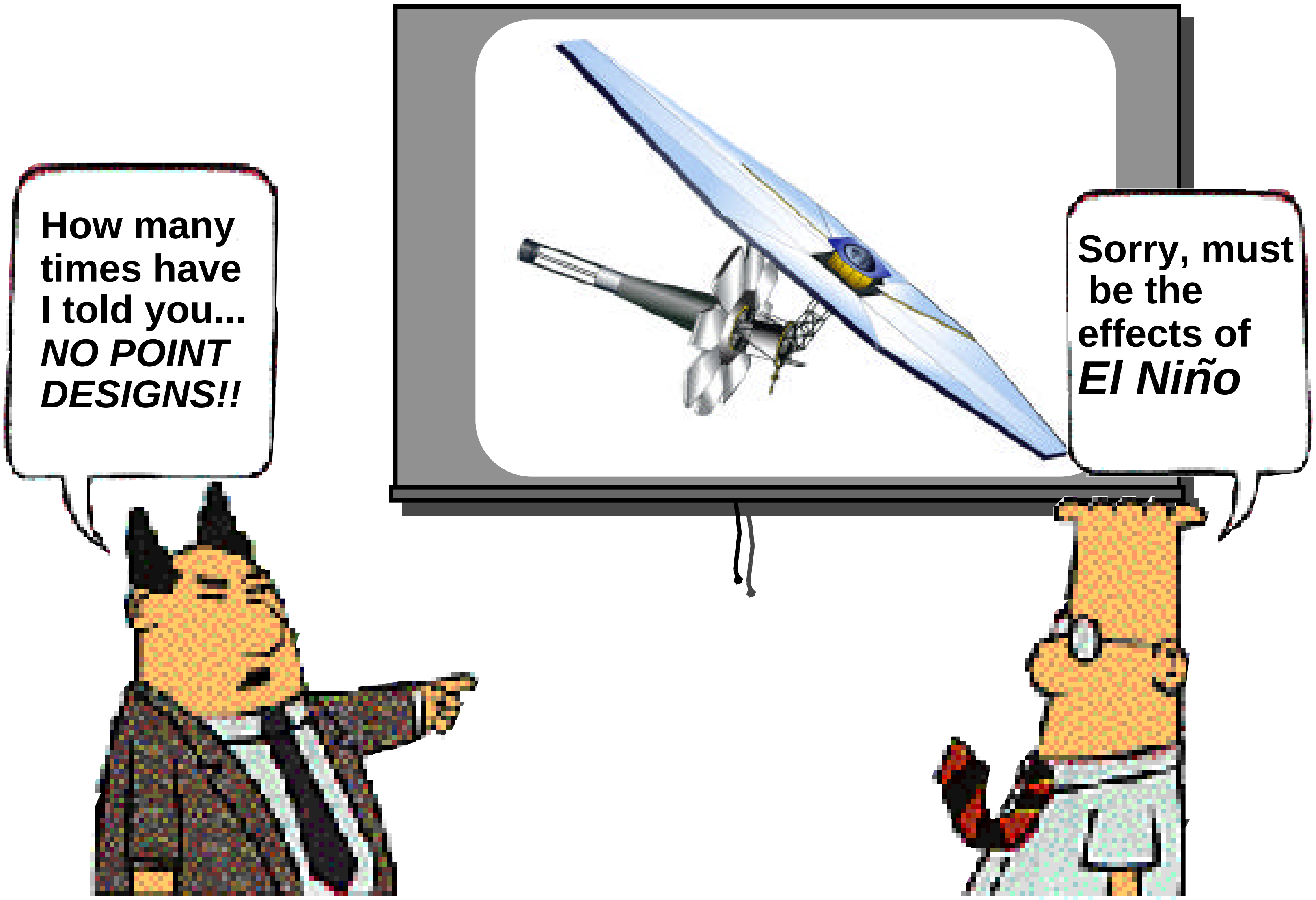
The Environment



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NGST Will Be Developed in a Cost Constrained Environment

Budget Breakout for a ten year mission in Real Year Dollars:

- **Pre-development technology SR&T: $242M ($214M ‘97)**
- **Manufacturing of NGST: $674M ($500M ‘97)**
- **Launcher, Mission Ops: $653M ($412M ‘97)**

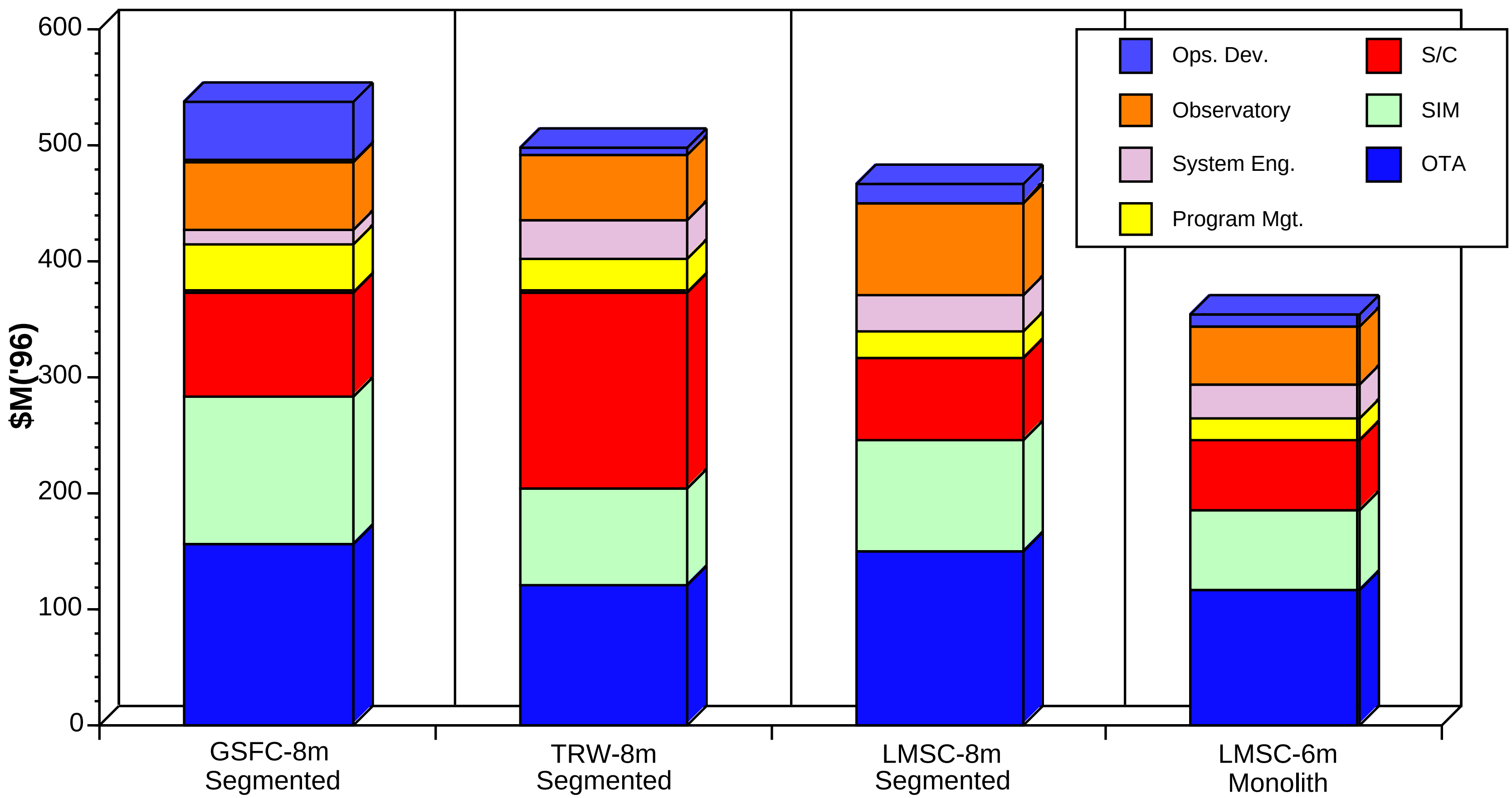
The NGST Conundrum...

- Mars Pathfinder in some sense validated Mr. Goldin's "Better-Faster-Cheaper" philosophy
  - So did SSTI/Lewis
- Yet, NGST is somewhat different by virtue of the larger astronomical community and the Hubble legacy

***Herein lies the NGST (and perhaps the larger Origins) Condundrum*:**

How does the NGST project team "manage" the risks characteristic of a $500M NGST ($96), given on the one hand our Administrator's mandate to be "bold" and on the other hand the risk averse nature of Center and Industry functional management and review committees?

Manufacturing Cost Estimates



Manufacturing Cost Estimates for the Three Independent Studies. These estimates do not include predevelopment studies (Phase AB), technology development, and contingency (~30%). The three teams have allocated certain development costs to different cost elements.

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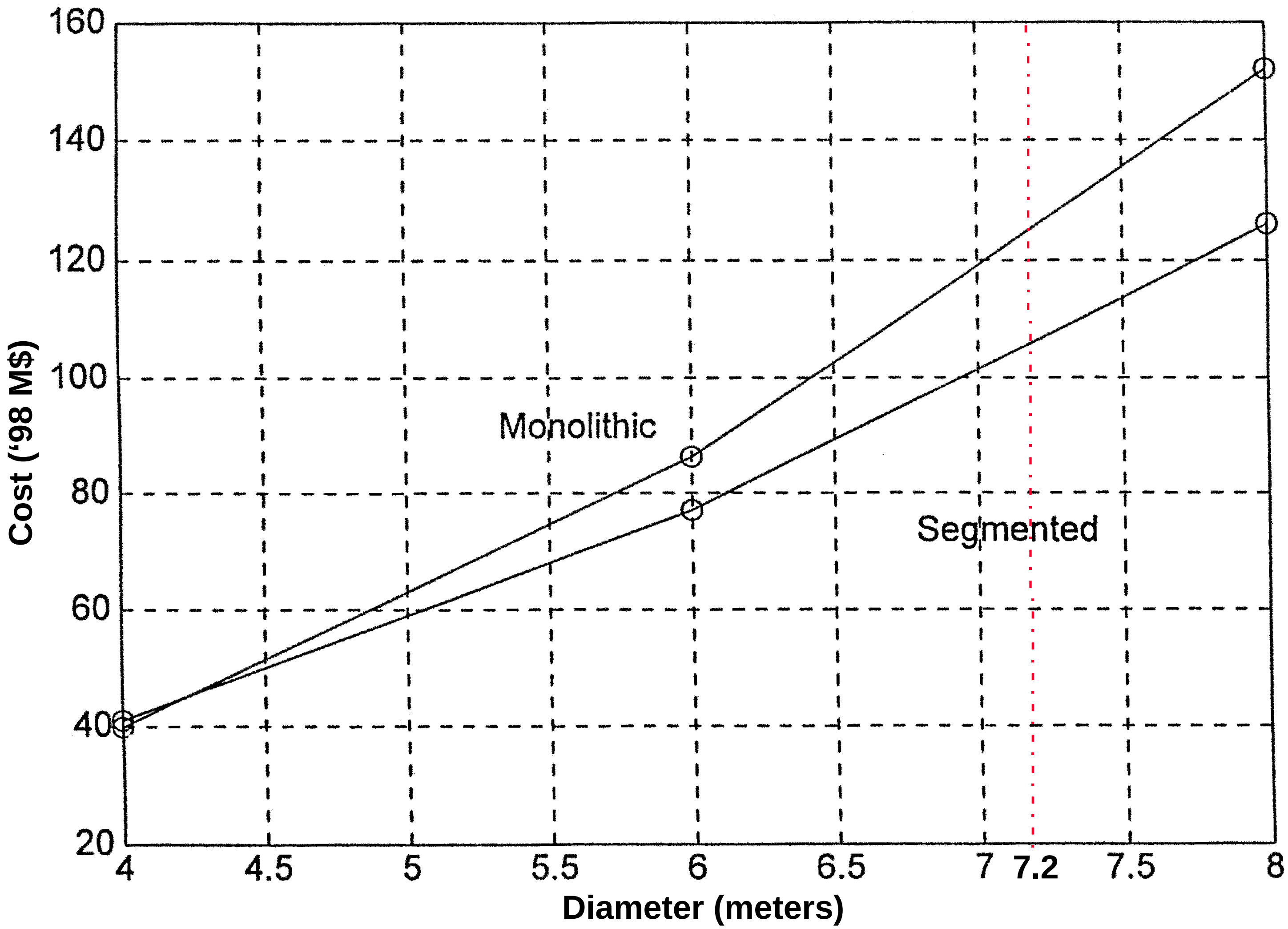
Segmented vs. Monolithic Mirror OTA Cost Comparison

OPTICAL RESEARCH ASSOCIATES



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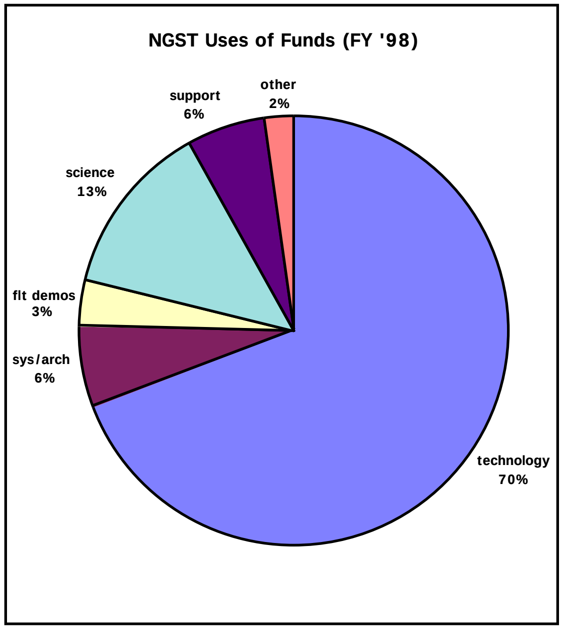
NGST LIFE CYCLE COST

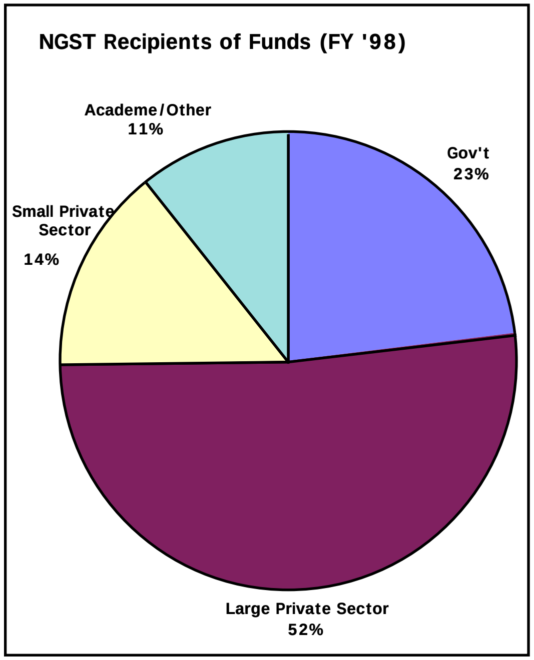
$M Real Year

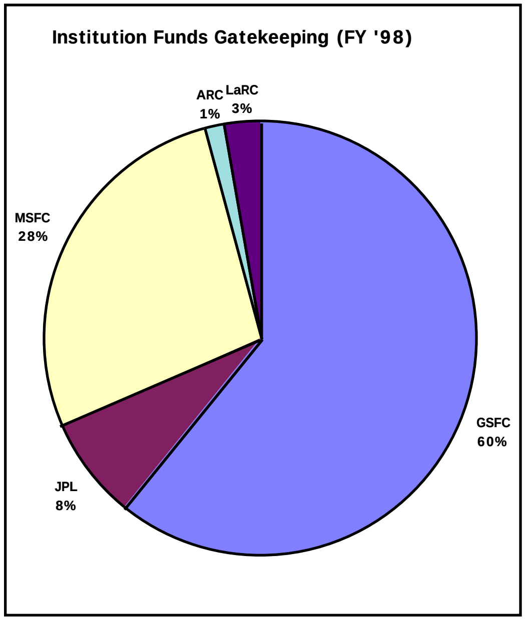
	FY '97	FY '98	FY '99	FY '00	FY '01	FY '02	FY '03	FY '04	FY '05	FY '06	FY '07	FY '08	FY '09	FY '10	($M)
Pre-Phase A	3.1	6.0													9.1
Phase A			8.6	15.4											24.0
Phase B					25.3	26.5									51.8
Phase C/D							75.1	156.1	175.8	166.9	100.1				674.0
Launcher								38.5	62.7	8.8					110.0
Phase E Ops												16.9	17.3	. . .	189.1
Phase E Data Analysis												31.6	32.4	. . .	353.5
Technology Development	2.7	16.4	16.2	21.5	23.4	22.7									102.9
Flt Technology Demo		0.7	5.3	10.9	18.6	19.3									54.8
TOTAL	5.8	23.1	30.1	47.8	67.3	68.5	75.1	194.6	238.5	175.7	100.1	48.5	49.8	. . .	1569.2
TOTAL $FY'97	5.8	22.4	28.1	42.9	58.0	56.8	60.0	149.6	176.4	126.3	70.0	33.0	33.0	. . .	1126.2

...Requirements thru FY'17

Deployment of Resources
FY '98 SR&T Budget







- $23.1M NOA FOR FY '98
  - $3M WILL BE CARRIED OVER TO HELP OFFSET THE FY '99 FUNDING SHORTFALL

Next Generation Space Telescope

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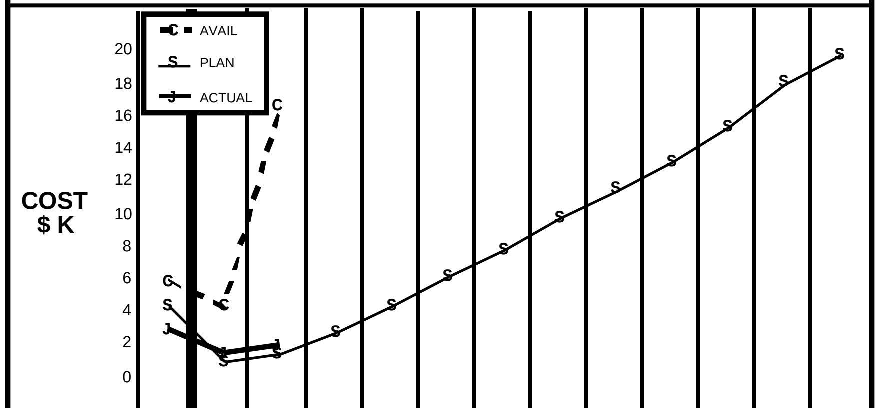
Cost Accountability & Credibility

- Early Emphasis on cost in both the design process and the management process
- Resource ramp-up from \$5M to \$23M necessitated a rigorous cost plan and resources support staff to help manage to cost
  - Multi-center nature of the team presents new challenges and new opportunities
  - Other center help to share the procurement lead
- Cost management tools in place
  - STRAP cost tracking program
  - Contingency tracking
  - Suballots

GODDARD SPACE FLIGHT CENTER
APPROVAL: B. SEERY
ACCOMPLISHMENT: G. GOODMAN

NEXT GENERATION SPACE TELESCOPE
POP 97-1
TOTAL

COST
STATUS AS OF:11/30/97



	SEP	OCT	NOV	DEC	JAN 98	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
AVAIL	5.9	4.3	16.7										
PLAN	4.3	0.9	1.5	2.8	4.3	6.2	7.9	9.8	11.5	13.2	15.4	18.1	19.8
ACTUAL	3.0	1.4	2.0										

FY 98

Next Generation Space Telescope

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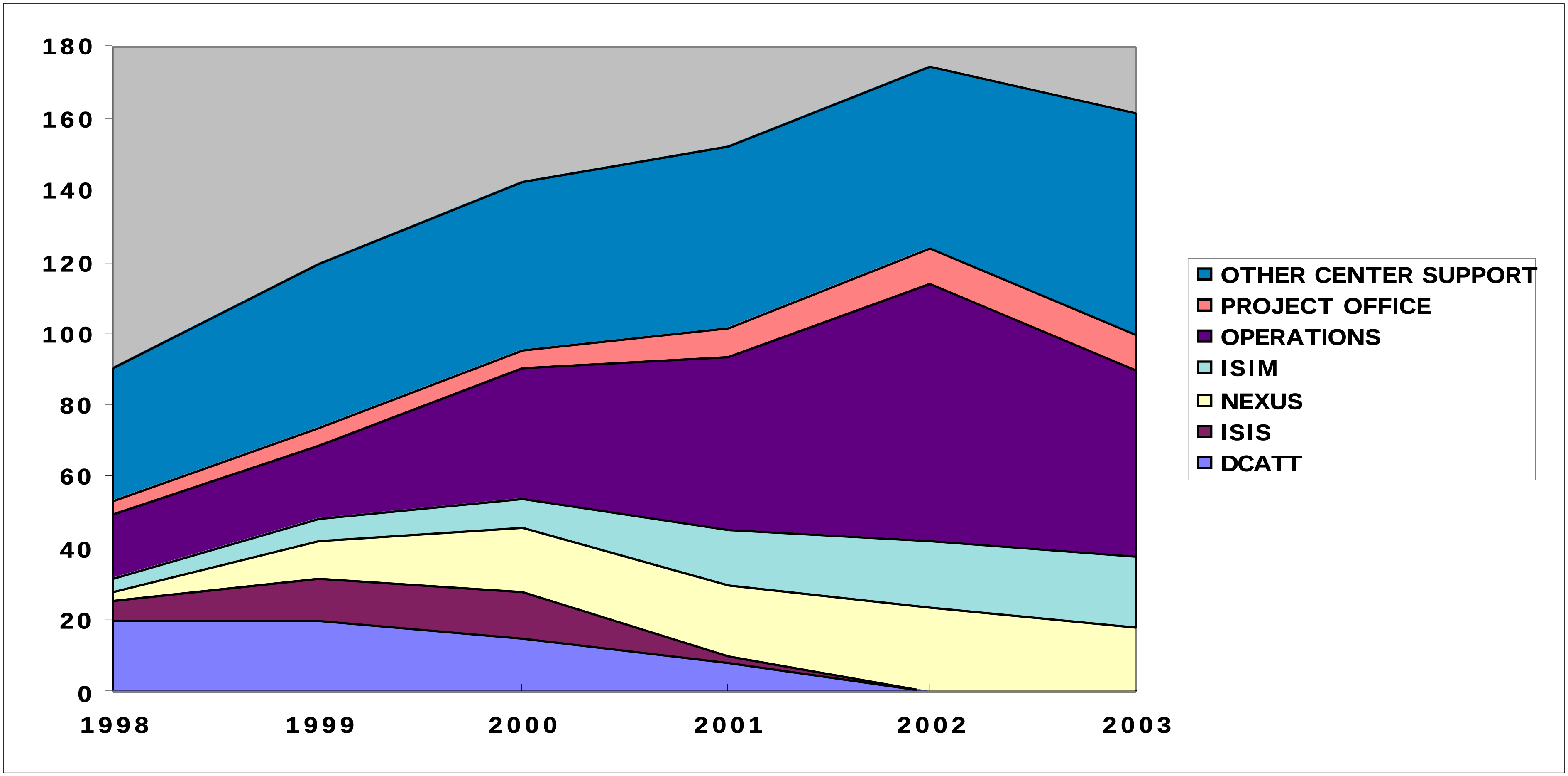
NGST Civil Servant Manpower



Team NGST - A Strategy for Drawing on the Best Talent and Expertise

- **Early Assessment of Core Competencies in Industry, Academia, and the Agencies led to the following strategy**
  - **Maximum leverage from the industry resulting from work they have done for non-NASA customers in the following areas:**
    - **Large deployable structures**
    - **Spacecraft**
    - **Lightweight mirrors**
- **We have engaged the relevant players through competitive procurements**
- **Maximum leverage from the NASA team due principally to institutional strategic plans and core competencies yields the following areas of focus and specialization:**
    - **Science**
    - **Operations technologies**
    - **Optics/Active Optics**
    - **Science instrumentation**
    - **Modeling & simulation**
  - **When the expertise is in NASA, NGST will present ample opportunities to transfer the knowledge via:**
    - **Yearly Tech Challenge**
    - **Open IPT's**
    - **Tech validation flights & testbeds**

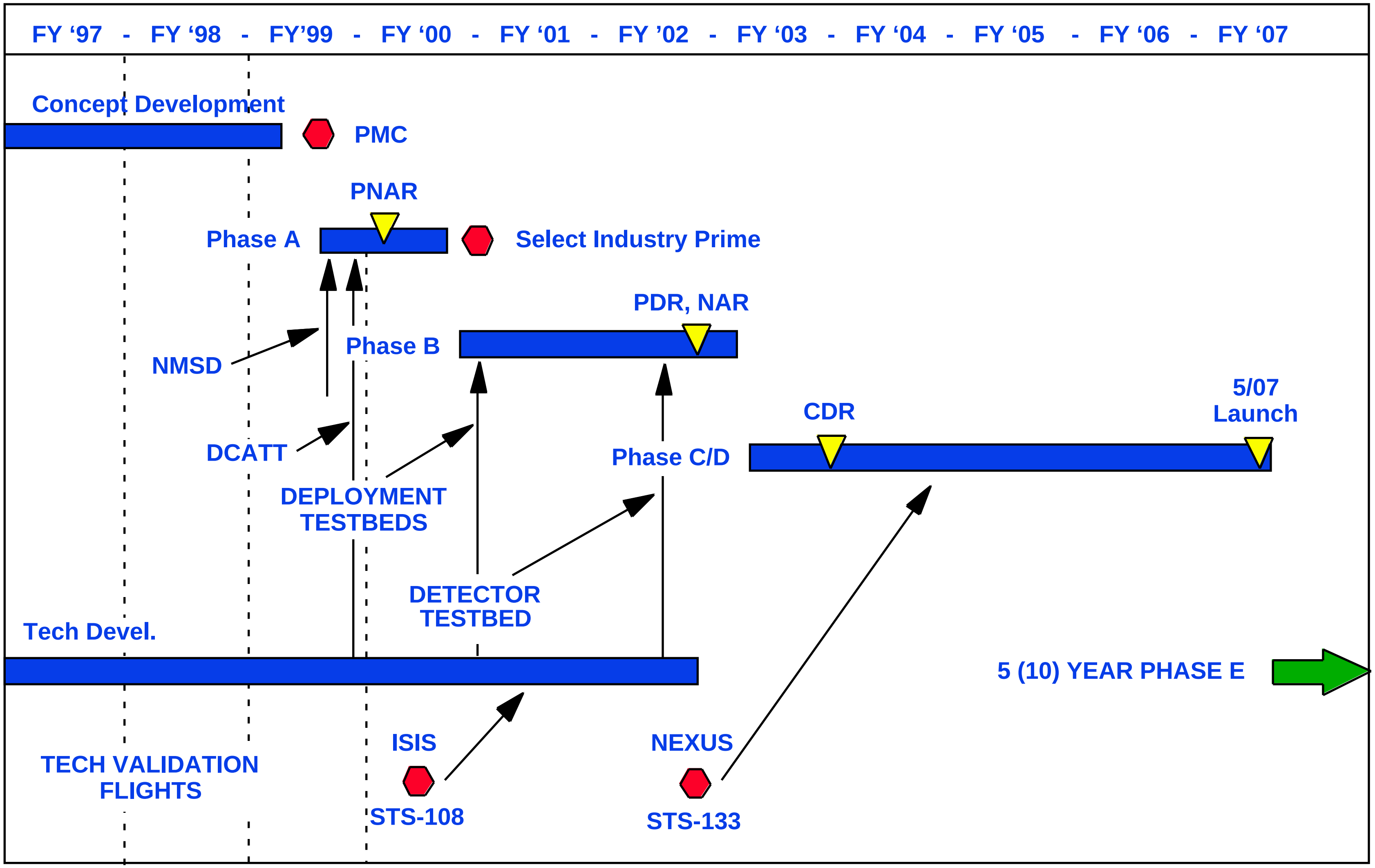
Ad Hoc Science Working Group

Charter: Ad Hoc Science Working Group provides guidance to the project during early design phase

Areas of Specific Interests:

First Objects in the Early Universe, z > 10	*Avi Loeb*
Metal Production in the Early Universe (SNe)	*Bob Kirshner, Avi Loeb*
Star Formation in the Early Universe	*Simon Lilly*
Galaxy Formation in the Early Universe	*Mike Fall, Massimo Stiavelli, Simon Lilly, Jon Gardner*
Dust enshrouded AGN and Star Clusters	*Simon Lilly, Marcia Rieke*
Interstellar Medium	*Marcia Rieke, Mike Rich*
Stellar Astrophysics and Evolution	*Bruce Margon*
Stellar Populations	*Mike Rich*
Star Formation, IMF, Protostars	*Mike Meyer*
Formation of Planets and Planetary Systems	*Mike Meyer*
Wide Field, Ground-based Surveys	*Bruce Margon*
Deep Ground-based Surveys	*Simon Lilly, Jon Gardner*
SIRTF	*Marcia Rieke*
Integrated Science Instrument Module	*Don Hall, Rieke, Simon Lilly*
IR Detectors	*Don Hall*
Science Operations	*Mike Rich*
Design Reference Mission	*Massimo Stiavelli*
NGST Study Scientists	*John Mather, Peter Stockman, Peter Jakobsen*

Provisional Development Schedule



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FY '98 Near Term Goals and Products

- **Goals**
  - **Expand Technology Portfolio**
  - **Produce viable architecture(s)**
  - **Generate revised resource estimates**
  - **Validate models**
- **Major products**
  - **Technology Implementation Plan**
  - **Revised DRM**
  - **Approved partnerships**
  - **Integrated Network/schedule**
  - **ISIS Program Plan**
  - **Technology "black book"**
  - **Integrated "2-D" model**
  - **Working prototype mirrors and actuators**

The NGST Challenge is to Use New Technology to Make the Mission Affordable

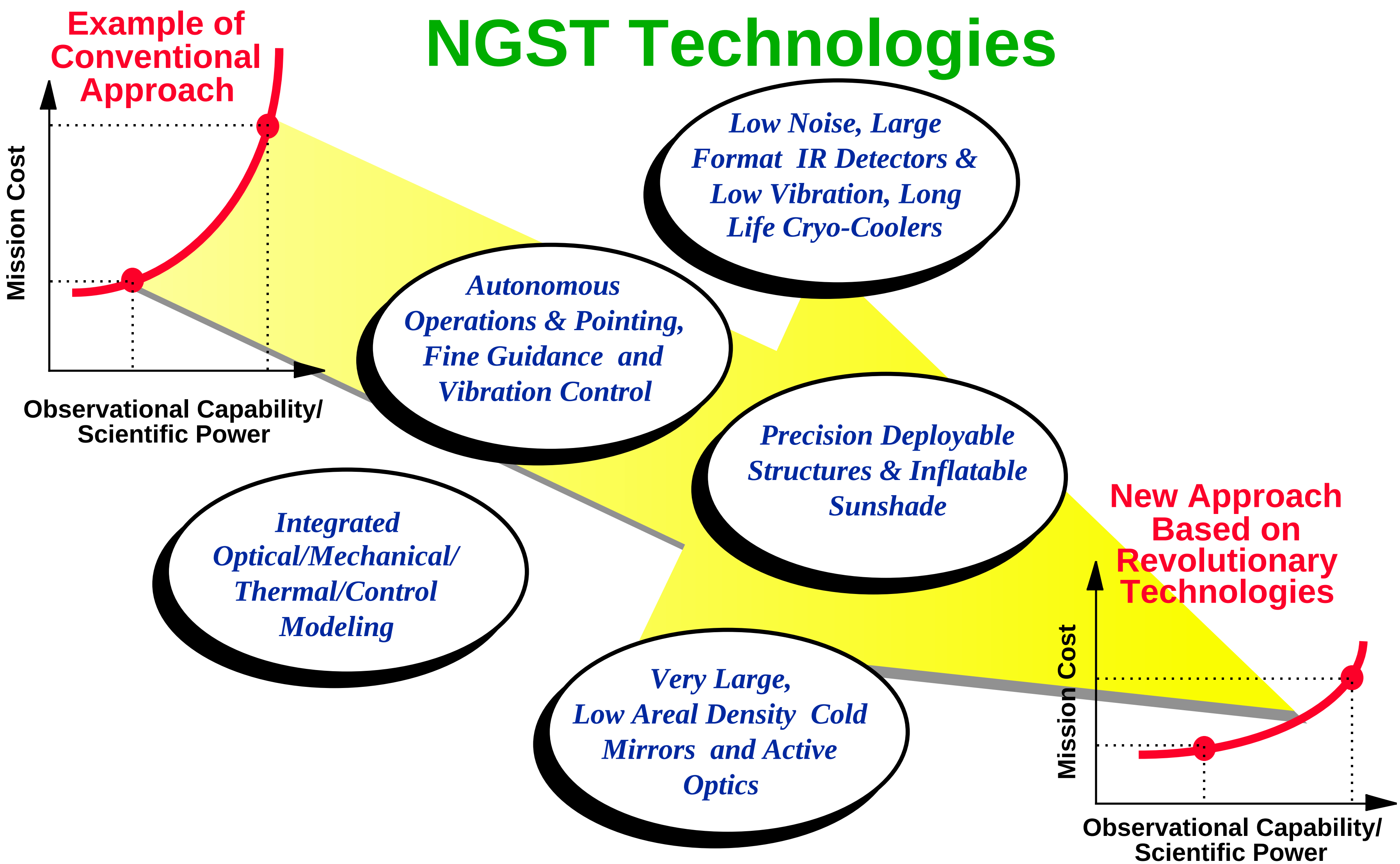

fig 035a

MAJOR TECHNOLOGY THEMES

ORDER OF MAGNITUDE IMPROVEMENTS IN SCIENTIFIC PERFORMANCE (APERTURE, SENSITIVITY, SPECTRAL) AT AN AFFORDABLE COST

- **Large filled apertures - tight psf cores/High Strehl**
- **Segmented deployable primary - low cost, scalable**
- **Computer rigidization of lightweight optics - enhanced stiffness**
- **Large inflatable structures for passive cooling - reduced weight and complexity**
- **64 Megapixel packground-limited arrays - sensitivity advantage**
- **Focused technology development guided by performance modeling tools**

Next Generation Space Telescope

Fig 97a

Next
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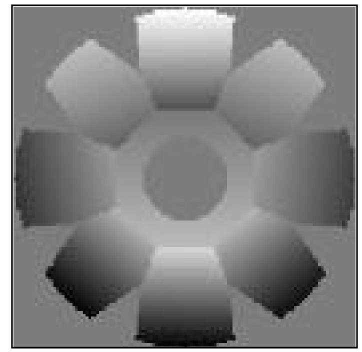
The Strategy

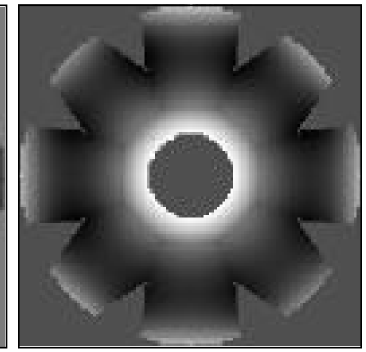
NEW CHART 131

Virtual Prototyping & Cyber Synthesis

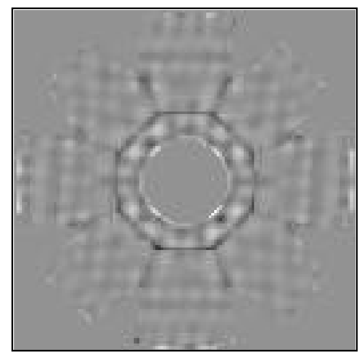
- End-to-end systems simulator being developed by a joint JPL/GSFC/MSFC/LARC Team
- Modern, object-oriented graphical programming using the MATLAB/SIMULINK Environment
  – Highly integrated graphics
  – Rapid QA on the models
- Example shown details the effects of post-launch cooling of the telescope structure and primary mirror thermal gradients
- Potential for systems-level simulation, computer-aided manufacturing, and anomaly resolution



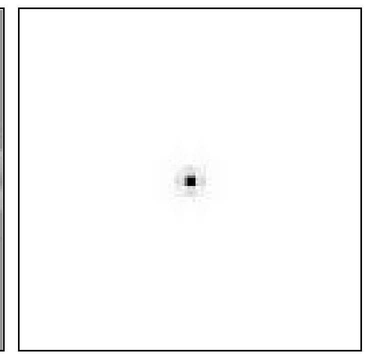
Raw on-orbit WFE
WFE = 34 μm



Following segment control
WFE = 717 nm



Following DM control
WFE = 33 nm



Following DM control
Strehl Ratio = 96 %

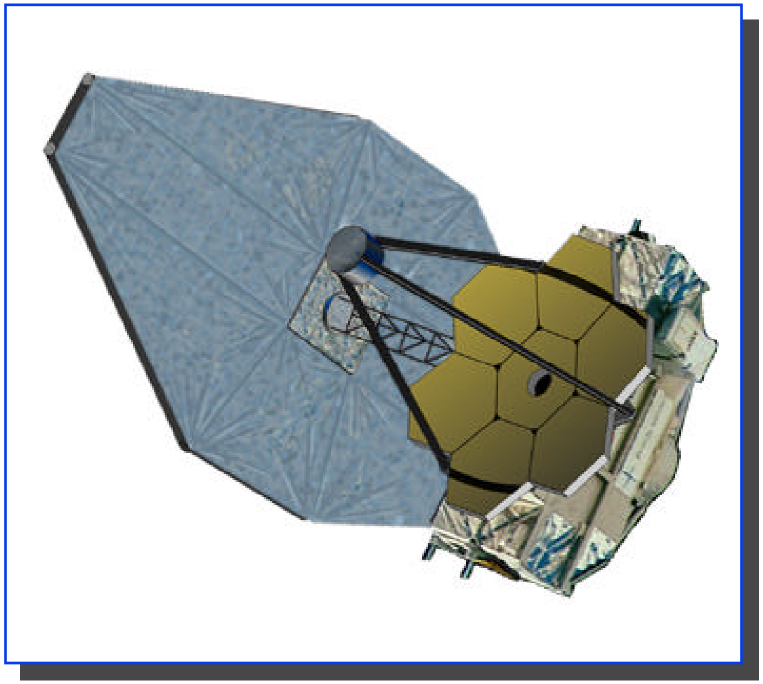
Next Generation Space Telescope

Telescope Risk Management Strategy

ITEMS/ COMPONENTS	MIRROR MATERIAL	DEPLOYMENT STRUCTURE	SEGMENTED PRIMARY	OTA
SOURCE OF EXPERTISE	Optics Industry & Academia	Aerospace Industry	Government & Optics Industry	Government & Areospace Industry
PROCUREMENT LEAD	Government - Directed Competitive Contracts	Industry - Directed	Government In-House	Industry
TECHNOLOGY INVESTMENT	• $16M NMSD • $2M Adv. Concepts	• $4M per year for Testbeds • Matching IR&D	• $3M per year for 3 years (DCATT)	• $50-60M over 4 years for flight test (NEXUS) • $12M over 2 years for ground testbed (System Testbed)
PRODUCTS	• 2-3 Viable Candidate 15 kg/m^2 Mirror Concepts • Understanding of the cost of scale-up and manufacture	• Ground Demonstration of high precision deployable backplane • Computer model validation	• Ground demonstration of alignment and phasing • Computer model validation	• In-Space, moderately cold, closed loop deployment & phasing demonstration • Demonstration of a 2 meter-class OTA according to the new cost curve • Validated integrated model

Pathfinder 3

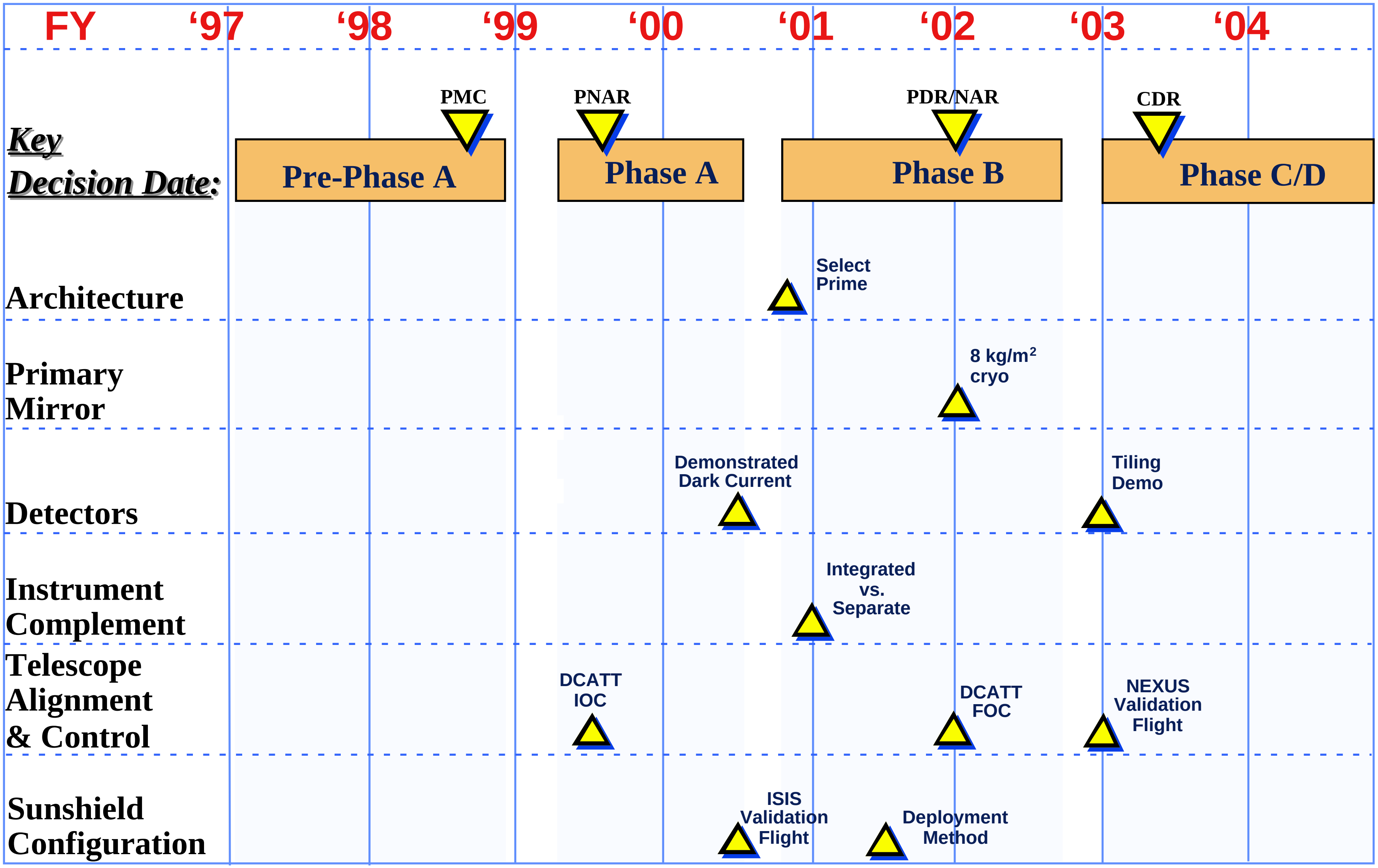
- Challenge to develop a cost effective approach to providing a diffraction-limited infrared aperture diameter which is larger than its stowed volume
- Nexus is integral to our strategy of demonstrating technological readiness. Further, it...
  - Validates the new cost curve
  - Roots out system-level problems
  - Energizes NASA Centers & JPL
  - Validates new partnering approaches
  - Transfers technology to industry
- Management approach adopted is to do Nexus in partnership with industry
  - Government is a major partner and incurs the appropriate share of risk
  - Industrial partner delivers the telescope payload based on their NGST architecture
  - DCATT team transitions from testbed to flight support in the wavefront control area



Nexus

Figure 068a

Key Technology Need Dates to Meet a Mid-2007 Launch Readiness



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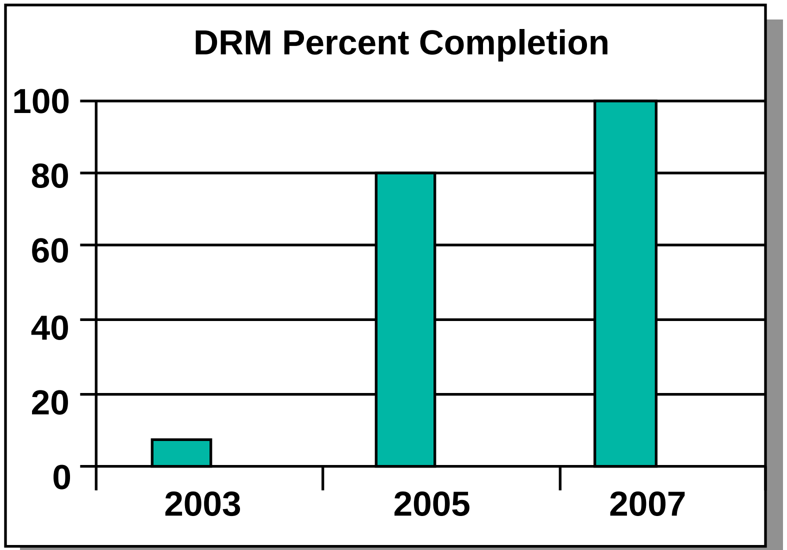
Metrics



Year of launch	2003	2005	2007
Mirror diameter	3.4	4.5	8
NIR Field of View	0.5’x0.5’	4’x4’	4’x4’
NIR Dark Current	0.1 e/s	0.05 e/s	0.02 e/s
MIR channel	none	none	incl
Sunshield	fixed	fixed	deployed

Note: values above are for illustrative purpose only

- METRICS NEEDED TO CONTINUOUSLY ASSESS TECHNOLOGY DEVELOPMENT PROGRESS
- “TIME TO CONDUCT THE CORE SCIENCE PROGRAM” DEEMED TO BE THE KEY TOP LEVEL SYSTEM METRIC
  - DRM

Acquisition Approach

Pre-A

- CAN 90-day study competition yielded 2 industrial partners in summer of ‘96
  - $200K per team plus matching corporate IR&D
- Competitive 18 month RFO competition produced 2 industrial partners in ‘97
  - Architecture Concept Studies - $1.5M each
  - Industry-Directed Technology Funds - ≥$1.5M each
  - Corporately-Matched Technology Funds
- Competitive Procurements in 1997 for the Ad Hoc Science Working Group ($100K), Cryogenic Acutators ($500K), Ultra-Lightweight Mirrors ($10M), and Science Instrument Concepts ($750K)
- In House “Integrated Science Insturment Module” (ISIM), Study under way in NASA; separate but coordinated effort in Europe (ESA)

Phase A

- Competitive procurement for Mission Analysis at the $12M level for each of 2 Industry Partners anticipated for the fall of 1998 - duration of the effort to be 12-15 months
- Advanced Mirror System Demonstrator Tech Development anticipated at the $5-10M level

Acquisition Approach (cont'd)

Phase B/C/D

- Competitive procurement for System Definition/Design (B) at the $50M level for 20 mos for a single Phase B Industry Partner
- This award would also include $18M for a systems level testbed observatory
- This contractor is anticipated to submit the Phase C/D/E Proposal for the observatory performance driven prime contract to manufacture, launch, and deploy NGST

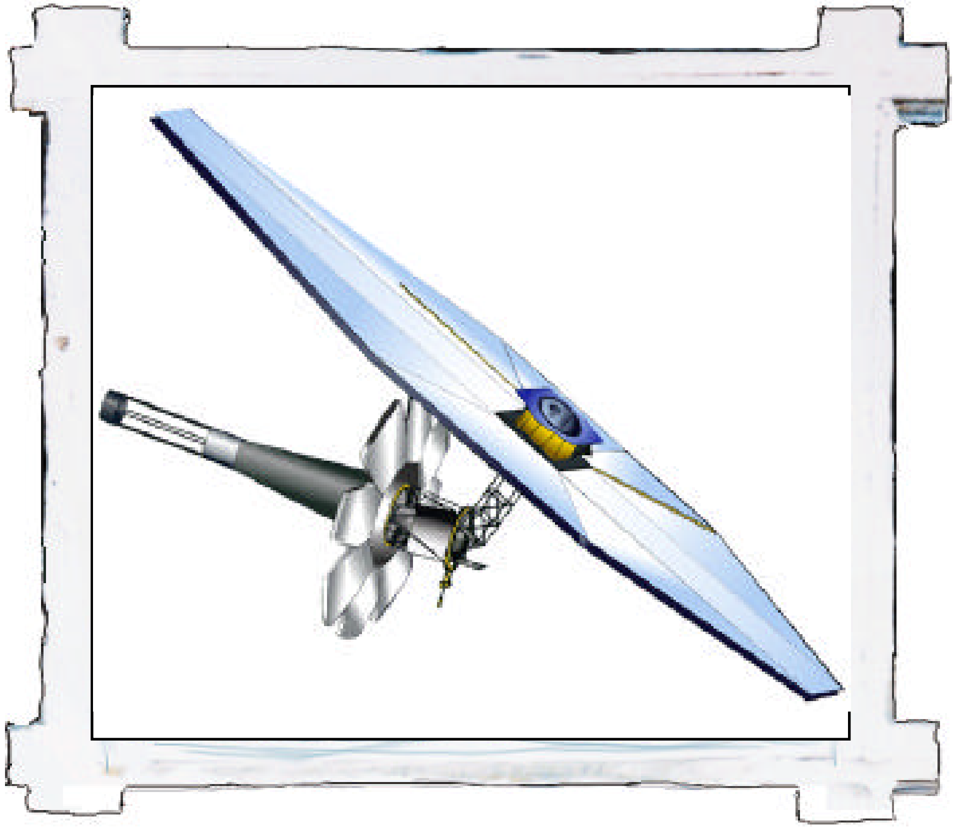
Phase E - Mission Operations, Maintenance, and Disposal

- Unclear at the moment what is the best, most cost-effective way for Phase E on NGST
- Issues which we are beginning to grapple with include:
  - Institute vs Prime for Science Ops
  - Government's role in Spacecraft Ops
  - Impact of advanced operations technology development on Ops staffing

Yardstick Design Template

Why maintain a Design Reference Concept and supporting staff?

- **Facilitates Derivation of Top Level Metrics**
- **Sets the bar high technologically**
- **Provides confidence that an NGST can be done for the cost**
- **Keeps the industry teams challenged**
- **Maintains the Smart Buyer-Smart Advocate**
- **Provides a “testbed” for the new CRP IPT**



NEW CHART (138)?

Partnering on NGST - Outlook

- **Background**
  - **Precedent set on HST**
  - **Committees established to pursue strategic alliances with internationals and NRO**
- **Premise**
  - **A key strategic alliance or joint venture has the potential to strengthen our advocacy position, increase momentum, and augment project resources and/or reserves**
- **Progress**
  - **Partnership with ESA established in early December and parallel studies in Europe to commence this month -$200M (US) contributions**
  - **Canadians are considering a contribution of $50M (US) and a decision to sponsor parallel studies is expected in February**
  - **NRO is considering co-investing in FY 99 technology development (R&T) and participating in the technology validation flights (OS&T) Presentation to senior NRO management in February**
- **Dilemma**
  - **Travel budget for GSFC civil servants inadequate to support levels of overseas travel anticipated**

Modes of Participation in NGST

- **Ad Hoc Science Working Group (ASWG)**
  - **Mather & Stockman, Co-Chairs**
- **NGST Integrated Product Product Teams**
  - **Open, but not funded participation**

IPT NAME	IPT LEAD/INSTITUTION	PRODUCT
SYSTEMS IPT	PAUL GEITHNER/GSFC	END-TO-END SYSTEM ARCHITECTURE
OPERABILITY IPT	DR. KEITH KALINOWSKI/GSFC	OPERATIONS TECHNOLOGIES & SYSTEMS
TECHNOLOGY IPT	DR. DAN COULTER/JPL	TECHNOLOGY ROADMAP
INSTRUMENTS IPT	DR. PIERRE BELY/STScI	INSTRUMENT TECHNOLOGIES & SYSTEMS
OPTICS TECHNOLOGY IPT	JIM BILBRO/MSFC	OPTICS TECHNOLOGIES
COST & PROCESSES IPT	PAUL GEITHNER& LISA GUERRA/GSFC	COST METRICS & MGT. PROCESSES

Figure 139

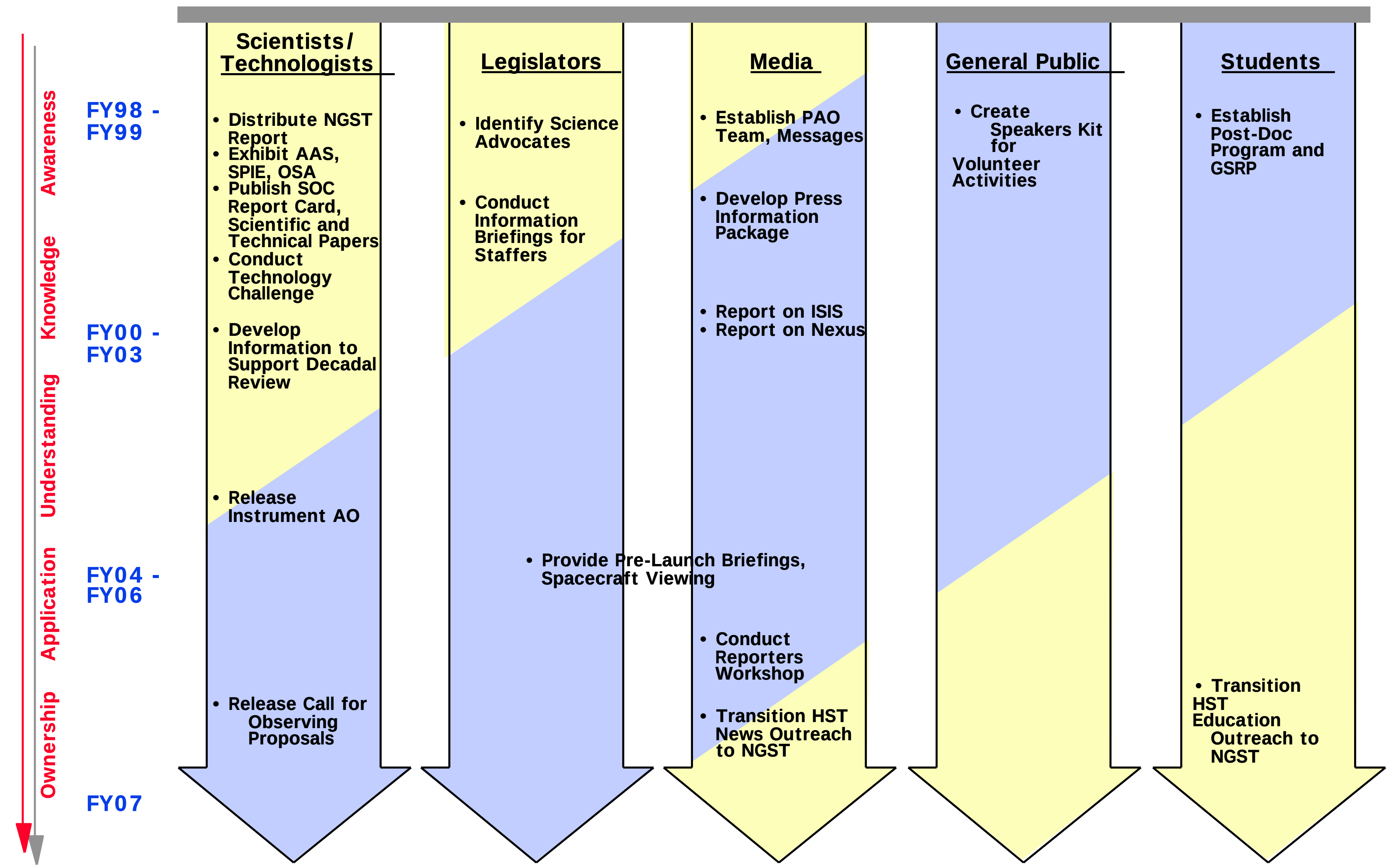
NGST: Risk Management Approach is to develop a cadre of flexible tools to ensure that the project is robust to glitches in funding, schedule, and performance

- Investment in **New Technologies**
  - Early when they can help you the most,
  - Recognize that not all new technologies need to be successful to make technology development cost effective,
  - At the companies which will make the flight systems,
  - And concurrently develop the test and validation plan to know when the technology is ready
- Implementation of **Integrated Systems Engineering** in order to
  - Optimize design by using integrated modeling and test-beds to lower cost; use model to track risk and error budgets,
  - Choose materials and sub-systems that make the overall system design simpler, more robust, easier to integrate and test,
  - Design for simple, robust Operations from the beginning,
  - Utilize an Integrated, Cross Diciplinary Engineering team with high degree of communication between members and recognition of innovation that lowers risk and cost
- Development of Modern, Efficient **Management Techniques** to
  - Optimize contracting strategy
  - Identify risk early by developing a validation/verification matrix keyed to schedule
  - Have a technical metric which measure the delivery of the product, not just the development of the tools,
  - Have a cost/benefit metric to aid in decision making,
  - Develop transparent schedules,
  - Fly when ready

Stretch IPT Provides a Mechanism to Introduce "Out-of-the-Box" Thinking into the Project

- Stretch Study leads report directly to the Project Manager until such time as the concept is matured enough to submit it to a full systems engineering analysis by the Systems IPT
- Duration of a stretch study is short; of order a few months
- Current Stretch Activities:
  - Characterization of a 1 meter membrane reflector at optical wavelengths. -Dan Marker/AFRL ($20K/96)
  - Robotic deployment of the telescope in LEO (on station) -Lloyd Purves/GSFC, SPAR/Canada, Chet Atkins/U of Md ($50K/97)
  - Shuttle/IUS launch of NGST; analysis of the cost benefit of checkout in LEO and possible changes to the telescope configuration afforded by STS launch
- Stretch IPT lead still TBD - NASA wide announcement did not bear fruit; project request to Center Director for a new hire from outside TBD

NGST Outreach Plan



LAUNCH AND OPERATIONS

L1130.001 OD7

SRB

BREAKING PARADIGMS...

- Weight
  - Low areal density active optics
  - Deployable optics
  - Miniaturization of electronics and avionics
- Cost
  - Pre-development SR&T program
  - Re-use of unclassified DoD hardware
  - Modest scale ELV
- Management
  - Testbeds and flight validations
  - Performance based contracting
  - Just-in-time technology
- Sociology
  - NASA teamed to support GSFC lead
  - Cost as an independent variable
  - Value-added government participation

Next Generation Space Telescope

What's Different?

- NASA's pre-development investment is 40% for NGST
  - Usual is 5%
- International partnership worth up to $250M (US)
- Co-investment opportunities with the DoD
  - NGST Senior IPT Leads have classifed accesses
  - Leads involved in joint agency technology roadmapping effort
- Sophisticated modeling tools permit cyber synthesis
  - Experience indicates less re-work during I & T
- Current pre-A really approaching phase A due to the in-house effort
  - In-house team both challenges and augments the funding-limited contractor team
  - Net result is an "A-Team" effort operating at the Phase A Level

Salient Features of NGST Worth Mentioning...

- As an astronomical tool, NGST will dominate the scene late in the next decade in a field that is so very visible to the public
- We are combining our mission architecture studies and advanced technology development with systems, process, and resource analyses to enable this revolutionary, engaging observatory
- NGST is a funded project with its own line in the FY '99 NASA budget
  - There is (finally) adequate pre-development funds to retire the risk of technology development
- We have a technology development roadmap which makes maximal use of other NASA funding sources and we are developing leveraged partnerships with non-NASA technology developers and providers
- We hope to show that savings from the use of advanced technology will exceed the cost of its development
- Scientists and engineers are working together, not to mention the fact that S&E's from multiple Centers, ST ScI, and JPL are, also

Current Status

- Science
  - ASWG selected & working
  - Initial DRM being re-worked by ASWG
  - Science floor and stretch goals developed
- Technology
  - Component technology development well underway
  - DCATT testbed under construction at GSFC, Building 5
  - Planning & design for ISIS in full swing
  - Segmented telescope/radius of curvature lash up near complete
  - Technology roadmap & implementation plans are complete
- Project
  - 4 major procurements currently underway; detector one anticipated for late spring
  - Project plan complete; revision to be consistent with 7120.5 planned for next period
  - SRB first meeting

Next Generation Space Telescope

Study Products for 1998

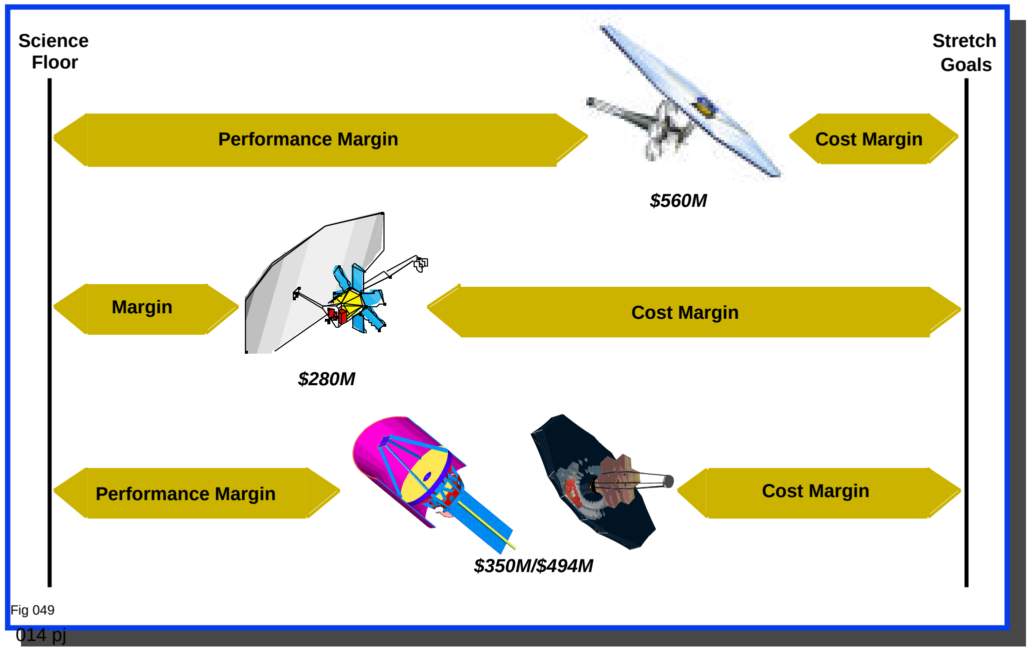
- Science
  - Revised DRM
  - Proceedings of the Goddard and Liege Science meetings
  - SOC report apres' AAS
  - Independent science & instrument HQs review this summer
- Technology
  - Ambient test of NMSD mirrors
- Project
  - NGST technology book in support of the Decadal Survey
  - Dave Pine's Independent Mission Analysis Group report
  - SRB report
  - New display and outreach plan
  - ISO-9001 compatible project plan
  - ESA study products (maybe Canada, too)
  - Letter of agreement between NRO and NGST (maybe AFRL, too)
  - C & P IPT report
  - SOW for Phase A architecture study

Open Issues to be Addressed in FY ‘98

- How to properly treat the instrument module given the potential for international collaboration
  - Integrated or not?
  - How does this drive cost?
- Observatory integration philosophy
  - System ground test?
- Applicability and Implications of performance based contracting
  - How are risk and reserves managed?
- Derivation of the new telescope cost curve
- Conversion from phased project management to formulation-approval-implementation approach
- The “wisdom” of a single Phase B contract
- SOW for Phase A and draft SOW for Phase B
- Mirror fabrication duration as a function of technology and methodology for fabrication
- Implementation of a model-driven design approach and seamless flowdown to implementation
- Transition fully to web-based project management

Science Floor or Stretch Goals - Which do we design to?

- **Issue**
  - **Do we bias our Phase A studies towards the floor or the stretch goals?**
- **Desirement**
  - **Keep it open for now, try to understand better the cost breaks and associated costs for achieving stretch goals, and let the industry prepare the "best performance for the price"**
  - **Use the cost and performance modeling of the yardstick concept to validate the industry cost estimates**
- **Bottom Line: Keep working towards the stretch goals until they begin to drive cost**
  - **Need somewhere to back off from**



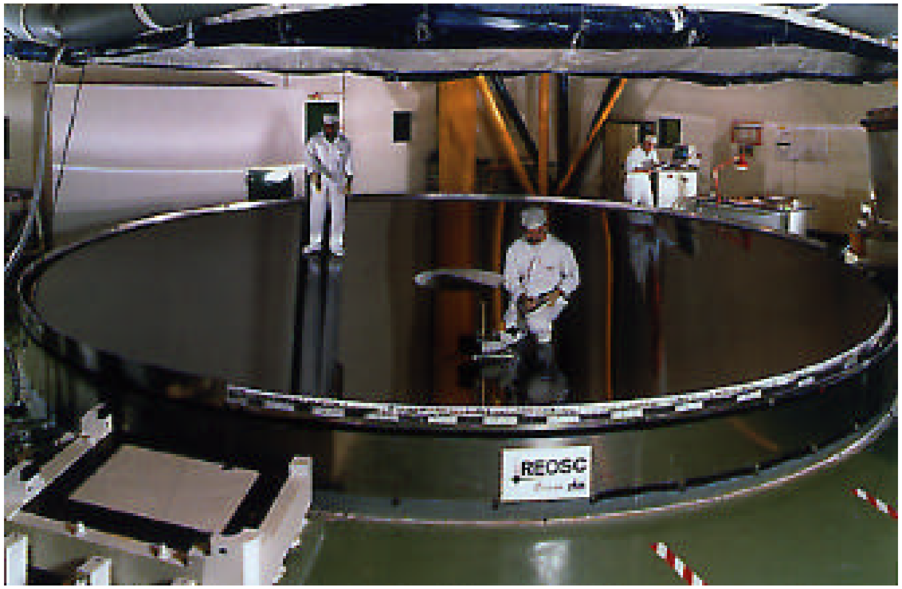
Performance and Cost Margins ('96 Dollars)

Project Manager Challenges

- **Keep the NGST alliances, which now include the internationals, intact and moving forward to innovate and solve problems**
- **Maintain the notion that technology is a system enabler and not just a problem solver**
- **“Manage” the various institutional imperatives for the betterment of the NGST**
- **Maintain an up-front emphasis on cost as an integral part of the design process**
- **Incur the “right amount” of risk in the design process**
- **Ensure that the technologists invest every technology dollar wisely and thus contribute to the project’s technology portfolio**
- **Move the project smartly through the sequence of programmatic gates to avoid getting bogged down**

NGST Mission Success Criteria

- **Outstanding Science**
  - **- Early Universe**
  - **- Galaxy Evolution**
- **Breakthrough Technology**
  - **- Mirrors**
  - **- Detectors**
  - **- Active Optics**
- **Affordable Cost**
  - **- < $500M ($96) Manufacture**
  - **- < $400M ($96) Launcher/OPS**



NGST - The Big Picture

John Mather, Study Scientist

Next
Generation
Space
Telescope

SRB
443.021

NASA IN ASTRONOMY

- **Make revolutionary discoveries using space-borne instruments**
- **Develop revolutionary technologies**
  - **Increase capabilities**
  - **Cut costs**
- **Go far beyond ground-based telescopes - space costs a lot, so results must be worth the effort**
  - **Keep an eye on the competition!**
  - **NGST can change the whole paradigm of astronomy**
    - **HST is only 1/4 size of Keck, Keck can follow up on HST results**
    - **No ground facilities come close to NGST sensitivity, but: they're cheaper, may eventually be larger**
- **Communicate results to the public**

MUCH IS EXPECTED FROM NASA

Why do Astronomy from space?

- No atmospheric absorption
  - Highest, coldest, driest ground and airborne sites aren't clear enough for most of electromagnetic and particle spectrum
- No atmospheric emission
  - Ditto
- Reduced telescope emission
  - Limits sensitivity for > 2 μm
- No atmospheric turbulence
  - Adaptive optics on ground partially successful, especially for > 1 μm
    - Like HST before COSTAR repair, but not stable
    - Very limited field of view
- Potentially, much larger apertures - no gravity, no wind!
- Long continuous observing - no day/night, no weather
- Excellent calibration stability

NGST CAPABILITIES FAR EXCEED GROUND BASED FACILITIES

NGST ADVANTAGES

- **0.5 - 1 micron: wide field, high angular resolution imaging**
  - **adaptive optics on ground has limited field of view, limited sky coverage, low and variable Strehl ratio**
  - **some airglow**
  - **targets are compact, < 0.1 arcsec, i.e. < seeing from ground**
  - **NGST 3 x larger than HST**
- **1 - 2 microns: imaging and medium resolution multiobject spectroscopy**
  - **adaptive optics effective, but ground needs high resolution to see between lines, can't do many objects at once, some wavelengths are blocked**
- **> 2 microns: imaging, spectroscopy except very high resolution**
  - **ground based telescope emission very bright**
  - **atmospheric blockage at most wavelengths**
  - **NGST 10 x larger than SIRTF**

NGST ADVANTAGES DEPEND STRONGLY ON WAVELENGTH, GOVERN CHOICE OF SCIENCE

GROUND BASED TELESCOPES

- Mt. Wilson 2.5 M, 1917
- Mt. Palomar, 5 m, 1948
- 2 Keck, 10 m. Segmented optics!
- 2 Gemini, 8 m, IR optimized. Can test NGST instruments!
- 4 VLT, 8 m
- Subaru, and many other 8 m telescopes
- Sloan Digital Sky Survey, 2MASS (2 Micron All Sky Survey)
- SOFIA, 3 m, airborne
- Hobby Eberly, 11 m sphere, 1997
- Extremely large telescopes, >25 m, next generation ground telescope
- Adaptive optics, under development - many
- Interferometers, under development - Keck, VLT, Palomar, ...

ESSENTIAL NGST TECHNOLOGY DEVELOPED ON GROUND

GROUND BASED INSTRUMENT HERITAGE

- Cameras - wide field - NGST CORE REQUIREMENT
  - Filter wheels, polarizers
- Single object spectrometers
  - Dispersive:
    - Gratings
    - Prisms
    - Grisms
    - Cross dispersed echelle gratings
  - Tunable
    - Low resolution filters
    - Fabry-Perot
  - Spectral multiplexing - Michelson
- Coronagraphs - NGST POSSIBLE INSTRUMENT

NGST INSTRUMENTS TESTABLE ON GROUND

GROUND BASED INSTRUMENT HERITAGE

- Multi-object spectrometers
  - Integral field spectrometers
    - Lenslet arrays - POSSIBLE NGST INSTRUMENT
    - Image slicers - POSSIBLE NGST INSTRUMENT
    - Tunable filter, Fabry-Perot - POSSIBLE NGST INSTRUMENT
    - Michelson interferometer
  - Objective gratings and prisms
  - Laser drilled aperture masks for grating
  - Fiber coupled input to grating
    - Hand inserted, or robotic
  - Future: digital micromirror array input switch - NGST BASELINE CONCEPT

CRUCIAL REQUIREMENT FOR NGST SCIENCE

SPACE TELESCOPES

- OAO
- IUE
- IRAS: 60 cm Be; 8-120 μm; 1982; 10 mo.; LEO
- COBE DIRBE; 20 cm Al; 1-240 μm; 1989; 10 mo.; LEO
- HST; 2.4 m glass; 0.115-2 μm; 1990; 15-20 yr.; LEO
- EUVE
- ISO; 60 cm glass; 3-240 μm; 1995; 18 mo.; 24 hr
- WIRE; 28 cm; 12, 25 μm; 1998; 4 mo.; LEO
- FUSE
- SIRTF; 85 cm Be; 3-180 μm; 2001; 2.5 yr.; 1 AU
- AXAF

MAJOR SYSTEM ENGINEERING CHALLENGES CAN BE SOLVED

ADAPTIVE OPTICS

- Turbulence from ground level to 10 km
- Coherence length r_0 =10 cm $(l/0.5\ \mu m)^{1.2}$ for typical 1 arcsec seeing; sometimes seeing is 0.25 arcsec
- Coherence time = r_0/ wind speed = 2 to 5 msec at visible at good site, increasing with wavelength
- Isoplanatic angle = r_0 / effective atmospheric thickness = 5 arcsec at 0.5 μm , 10 arcsec at 1 μm , 25 arcsec at 2.5 μm
- Can correct well only near a bright star or laser reference
- Laser reference has limited brightness - saturation of sodium scattering
- Laser reference doesn’t correct image motion, need additional tip-tilt system

AO WORKS WELL ONLY FOR > 1 μm

ADAPTIVE OPTICS SYSTEMS

- Bright star or laser reference beam scattered from upper atmosphere (Rayleigh scatter or sodium resonance line)
  - limited coverage of natural guide stars
- Wavefront sensor (Shack-Hartman, interferometer, etc.).
  - Photon noise,speed, and number of pixels limits performance.
  - Need at least 1 pixel per coherence length, 100 photons per coherence time. In practice, need more pixels and higher frequency for feedback stability.
- Computer to convert sensor output to control signals
- Deformable mirror (at primary or an image of it). Must have enough speed and pixels to match sensor.
- Science instrument must maintain wavefront quality.

GROUND BASED DEVELOPMENT OF NGST ADJUSTMENT METHODS

POINT SPREAD FUNCTION OF AO

- Strehl ratio is ratio of brightness of central peak to that with perfect optics
- Expected Strehl ratio 0.1 at 0.3 μm , 0.3 at 0.5 μm , 0.6 at 0.8 μm , 0.9 at 2 μm , variable with weather
- Remainder of light distributed over halo of size l/r_0 , typically 1 arcsec at visible, less at IR
- Strehl ratio, core/halo ratio both variable in time and space
  - Photometry not stable! need major effort to calibrate whole field at once
- Difficult to look close to bright objects because of halo - dynamic range only ~1000, vs. HST ~33,000
- Resembles HST before COSTAR corrective optics, but variable
- In principle, could work much better with many more phase adjustments, looking very near a few bright stars

AO DIFFICULT TO CALIBRATE AND USE FOR QUANTITATIVE SCIENCE

Next Generation Space Telescope

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STRONG SUPPORT FOR NGST

- Origins theme touches deeply felt public interest
- HST pictures constantly in the news
- Scientific discoveries startling and important
- Huge international HST user community, needs successor after 17 yr.
- NASA team effort successful - many NASA centers, industry, university people strongly involved
- Open to advice and participation from community
- Competitions pull forth good ideas, demonstrate opportunities for future funding in fair and open way
- Technology development central theme - Goldin vision
  - Benefits from huge Government investment in space optics
  - Benefits to other Government space activities
- Faster, better, cheaper (not the same as smaller!)
  - Our biggest challenge!

MUCH IS EXPECTED - WE'RE IN THE SPOTLIGHT

Next Generation Space Telescope

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AFTER NGST?

- Next Next Generation Space Telescope could have:
  - Larger aperture, better optical figure
  - Colder temperature
  - Better detectors
  - Better instruments
  - Robot serviceability
  - Shorter or longer wavelength coverage
  - Lower background zodiacal light farther from Sun
- Planet Finder Array - benefits from NGST science and technology
  - Cold IR telescopes in interferometric array
  - TBD configuration
    - multiple payloads in formation
    - deployed or assembled truss
  - Requirements depend on zodiacal light here and in exo system
- Advanced imaging SIM using much larger apertures and baselines

NGST NOT THE END OF THE LINE - DON'T OVERFILL